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## A Centrifugal Tensile Tester for Snow

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A new centrifugal tensile tester has been designed for snow samples. The new design corrects many of the deficiencies of the older design.

Keywords: Snow avalanches, snow management, tensile strength, centrifugation.

The centrifugal tensile tester (Bader et al. 1951) has been used to test many snow specimens (Butkovitch 1956, Keeler 1969, Keeler and Weeks 1967, Martinelli 1971). Some inadequacies in the original design have become apparent with use. A new tester was therefore designed to overcome the following difficulties:

**Variable stress rate.**--With the older tester, the operator increased the spin rate until the sample failed. Thus the spin rate varied among samples, and it was impossible to determine its rate of increase precisely. Therefore, a photoelectric circuit was designed which turns off the drive motor when the sample fails. With the automatic turnoff, full power can be applied to the motor so that it accelerates rapidly, under its own inertia, to the point of sample failure. A recording of the tachometer output provides an accurate and permanent record of the acceleration of the spin rate.

**Inaccuracy of spin rate determination.**--The output of the older tester was observed visually on a tachometer dial. The operator attempted to observe the dial reading at the time of failure. Such a procedure can easily lead to both random errors by one operator and systematic errors among operators. With automatic turnoff and recording of the tachometer output, the

maximum spin rate attained by the tester is accurately recorded for each sample. This system greatly reduces the possibilities for operator error.

**Limited sample volume.**--Sommerfeld (1971) has shown that, in the type of brittle failure which occurs in the centrifugal tensile tester, the distribution of measured strengths is a function of the volume tested. To predict failure stresses of large volumes, it is necessary to know the distribution of the weakest strengths. The older tester used a tube smaller in diameter than an appreciable number (about 10 percent) of the largest flaws. Since the largest flaws determine the weakest strengths, it was desirable to design a tester which could accept significantly larger samples.

**Excessive sample handling.**--In operating the older tester, the sample was pushed from the sampling tube into a similar tube fixed to the machine. This operation often disturbed the lower density samples. Therefore, the new tester was designed so that the sampling tube could be placed directly on the machine without transferring the sample.

**Small notch radius.**--The older tester used a notcher with a 1/4-inch radius, both to retain the sample and insure that it broke in the center. It is possible that this small radius caused excessive stress concentrations and erroneous measurements. The new design incorporates notchers of 3-inch radius.

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**Excessive vibration.**--The older design depended on the motor bearing to hold the specimen tube. Because of the relatively light mounting, the machine vibrated in operation and the excessive vibration could have resulted in premature sample failure. The new design includes a massive turntable and large bearings, and is much smoother in operation.

### Automatic Turn-Off

Eight photo-diodes (Raytheon CK 1241)<sup>2</sup> are mounted on the main panel on a circumference 1 inch outside the turntable edge (fig. 1). A light is mounted above each diode in a cover that can be removed for sample loading.

When the momentary start switch (Sw 2, fig. 2) is pressed, silicon controlled rectifier (SCR) No. 1 (G.E.C.-C30D) is gated, putting approximately 160 v.d.c. across the motor. When a sample of snow breaks, it blocks the light from one or more of the diodes. The resistance of a diode, when clear, is 2K ohms, and when

blocked is 200K ohms. The increased resistance of the diode string raises the base voltage of the transistor (G.E.C. 2N335A) above its turn-on level (.3v). This in turn raises the gate voltage of SCR No. 2 (G.E.C.-C30D) above .8v, turning it on. With SCR No. 2 in a conducting capacitor state, C1 discharges through the 150 w. load light, putting an equal potential on both sides of SCR No. 1 and turning it off. Since voltage is no longer applied to the motor, it stops. Turn-off time is  $3 \times 10^{-3}$  sec., much faster than an operator's reaction time.

### Tachometer

The drive motor also drives a d.c. tachometer (Electric Indicator Co. CB-247), whose output voltage is directly proportional to r.p.m. This voltage is recorded on a strip-chart recorder (Esterline-Angus Speed-servo) eliminating a possible source of operator error. The output can also be read on a meter dial.

### Removable Sample Holder

Figure 3 shows the main features of the turntable, notchers, and sample holder. The sample holders were made from 5-inch (127 mm) o.d. 1/8-inch (3.2 mm) wall aluminum tubing. They are 7-7/8 inches (200 mm) long and contain

<sup>2</sup>The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

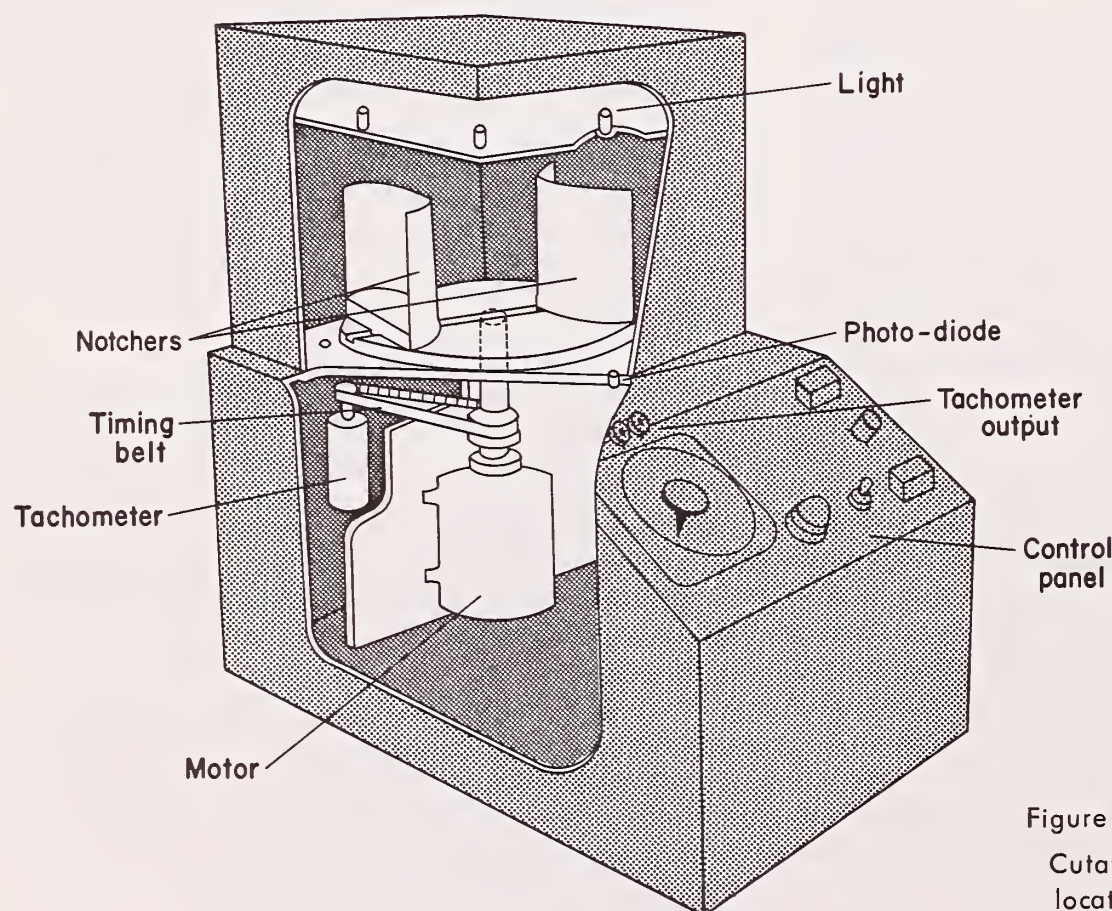


Figure 1.—

Cutaway view of spin tester showing location of various components.

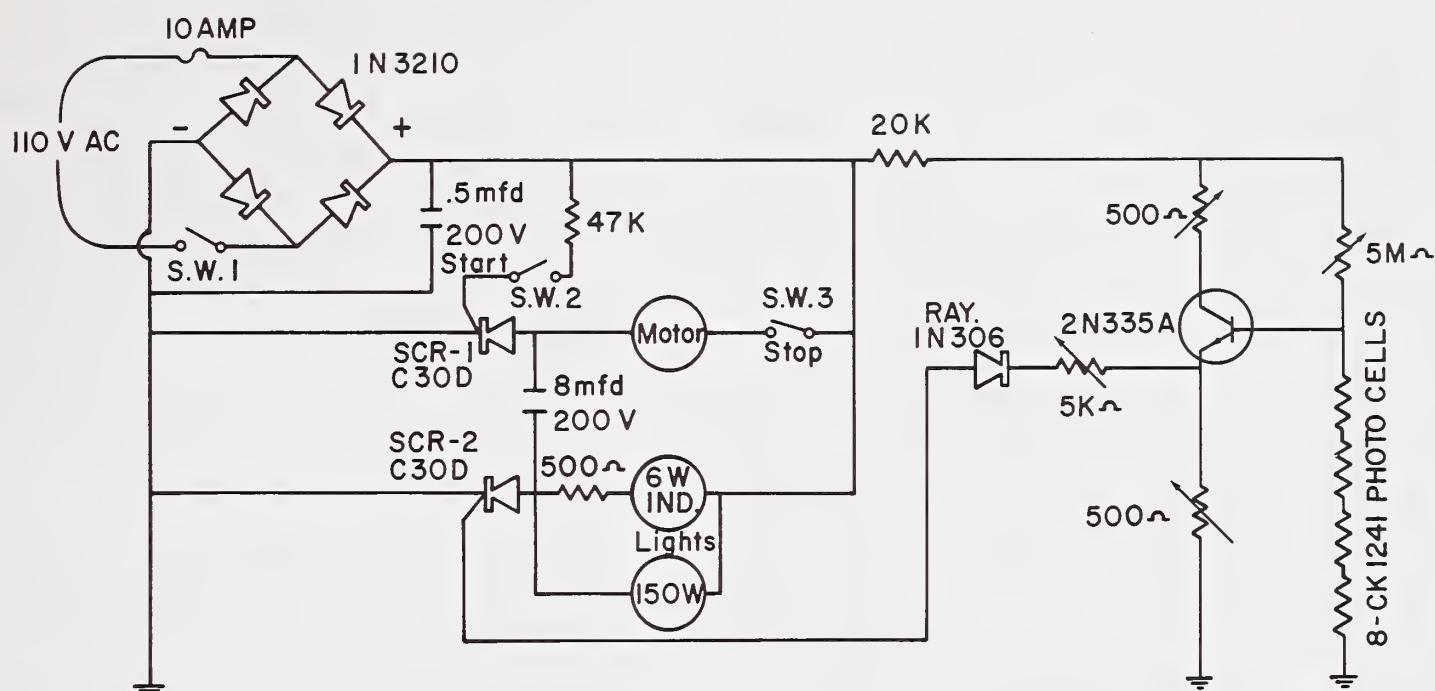


Figure 2.—Circuit diagram of start-stop circuit.

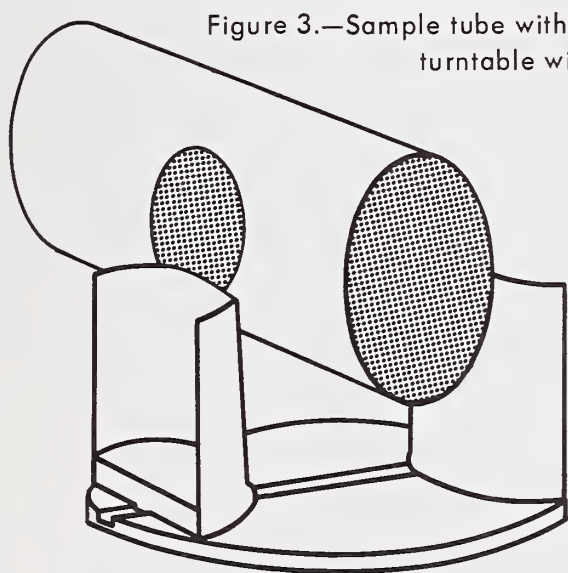


Figure 3.—Sample tube with cutouts and turntable with notchers.

### Larger Notch Radius

The narrow notchers of the older tester may have caused excessive stress concentrations. The 3-inch radius notchers on the new machine have stress concentration factors less than half those of the smaller notchers. Furthermore, the stress distribution in the centrifugal tester would make the difference even larger, since the effective notch length, in the nonuniform stress field, would decrease with the notch radius.

### Smoother Operation

The excessive vibration experienced with the older tester has been eliminated by:

1. Using a massive turntable to support the sample holder. The turntable was carefully balanced so that its center of rotation corresponds to its center of mass and it rotates smoothly. Because of the large mass of the turntable, even large inhomogeneities in the snow sample do not throw the system seriously out of balance. A further advantage is that variations in sample weight are insignificant compared to the total inertia of the system, so that the rate of stress application is very nearly the same for all samples.

a volume of 139.54 cubic inches ( $2.2867 \times 10^{-3} \text{ m}^3$ ) before notching. The width between the notches is 4.20 inches (10.67 mm).

Samples are cored from the sidewalls of pits with the sample holders. The holders are capped with plastic caps, carried inside, and weighed. When a holder is slipped between the notchers, the sharp edges of the notchers cut the snow sample, forming a narrowed cross section. An elastic band (not shown) is snapped across the holder to insure that it will not slip off. With the plastic caps removed from the holder, the sample is ready for testing. Since the sample is never removed from the holder it is much less susceptible to damage.

2. Using large, close-fitting bearings. These large bearings position the turntable shaft accurately and aid in smooth rotation of the turntable.
3. Isolating the motor from the turntable. The motor (Bodine Electric Co. NSE-34) is mounted on vibration-isolating mounts. The motor shaft is coupled to the turntable with a rubber coupler so that vibrations of the armature are not readily transmitted to the turntable.
4. Using a rubber belt for the tachometer drive. The older tester used a fiber gear to drive the tachometer, which may have introduced additional vibrations. The new design uses a rubber timing belt which gives the same nonslip drive as a gear without excessive vibration.

### Operational Tests

The new centrifugal tensile tester has now been used to test over 400 samples. A flexible sheet of plastic was added over the control panel to prevent water from dripping into the panel. No other operational difficulties have occurred.

There have been no zero strengths in the 400 samples, indicating that the large sample diameter is larger than any possible flaw. Also, the larger tubes are much easier to use and do not appear to disturb the snow as much as the smaller tubes used previously.

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